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ON THE DEVELOPMENT OF THE STOMATA OF TRADESCANTIA AND INDIAN CORN.[1]

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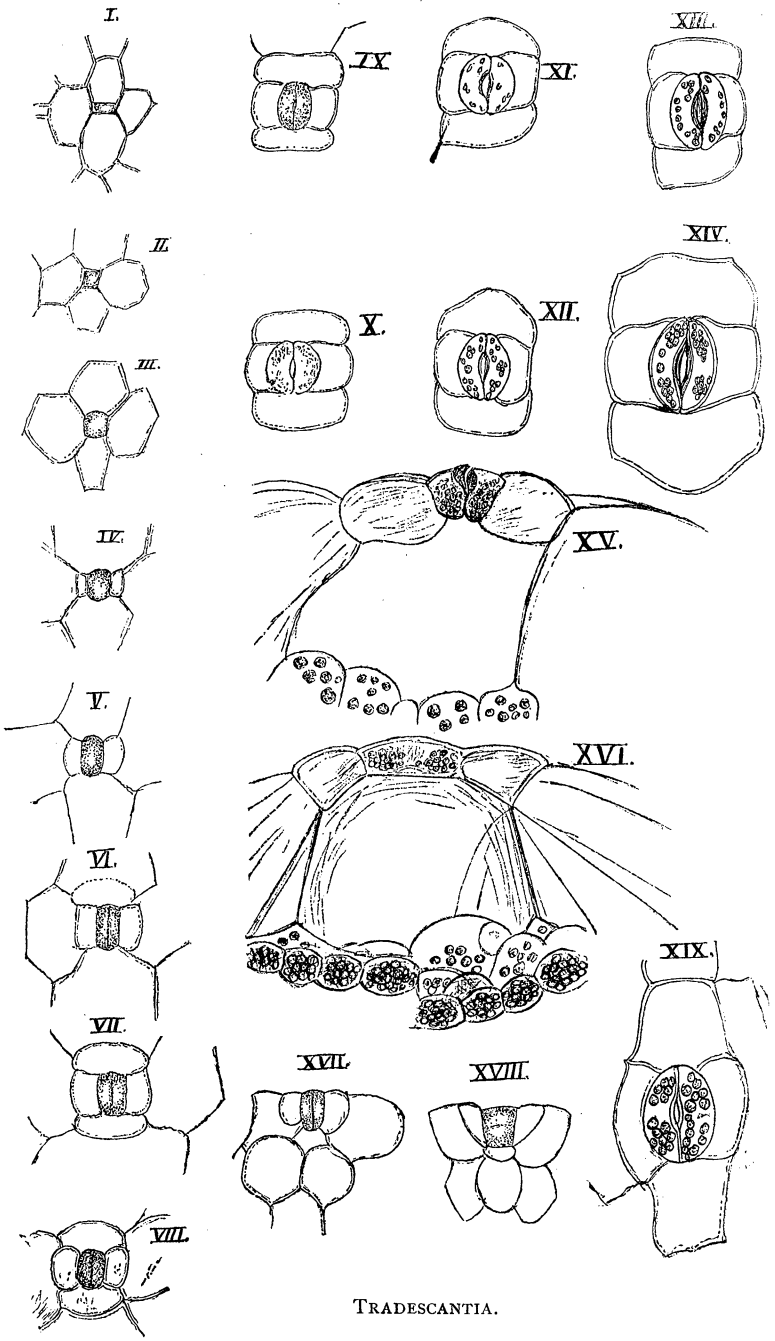
IF we examine a portion of the epidermis from the lower surface of the leaf of the common trailing Tradescantia (*T. vulgaris*), it will be seen to consist of polygonal cells, mostly irregular hexagons. At intervals, sometimes in nearly straight rows, in other cases irregularly, are found the stomata, each consisting of two semilunar guard-cells, meeting at the ends so as to enclose a central pore, whose walls are thicker than the external walls of the guard-cells. These guard-cells contain chlorophyll in distinct grains, while in the cells of the epidermis it is wanting. Grouped around the stoma are four cells, one on each side, one above and one below. These are very different from the ordinary epidermal cells, being nearly oblong in shape instead of hexagonal. On the stems the epidermal cells are elongated, and although accessory cells are still present, they are much longer and narrower (Fig. XIX). If a vertical section is made through the stoma, the guard-cells as well as the accessory cells are seen to be much shallower than the ordinary epidermal cells, so that a large air-cavity, equal to nearly the area of these four cells is formed beneath the stoma, and communicates with the external air by means of its pore. If we examine as young a leaf as can be had, the epidermis will be found to consist of nearly regular hexagonal cells. When a stoma is to be formed, a septum is formed across one end of a cell, at right angles to the axis of the leaf, thus pro-

[1] Special course of investigation of plant structure and physiology, conducted in the botanical laboratory of the University of Michigan.

PLATE I.



TRADESCANTIA.

ducing a cell whose upper surface is rhomboidal (Plate I, Fig. I).

This cell soon becomes nearly square, and at this time, lying between four nearly equal hexagons, it is a difficult matter to see from which it was produced (Fig. II). The cell lengthens so that in a short time it is longer than broad; and the ends are much curved, while the sides are nearly straight. The stoma increases very little in depth from the first, the subsequent growth being nearly all lateral. Soon after the stoma begins to take this oblong shape, two cells, of nearly equal size, and somewhat smaller than the stoma-cell, are cut out from the two epidermal cells at the sides of the stoma (Figs. IV and V), and a little later, in the same way, two similar cells are formed at the ends (Figs. VI and VII). Near the time of the formation of these latter cells, the mother-cell of the stoma shows a tendency to divide, the cell approaching in the meantime nearer and nearer the oval of the perfect stoma. A vertical septum is formed, dividing the mother-cell into two, and as growth progresses these separate in the middle, forming a pore leading to the space beneath (Figs. IX, X and XI). The contents of the stoma are, from the first, denser than those of the epidermal cells, but chlorophyll does not appear until the stoma has attained some size. As it increases in size, the chlorophyll becomes more evident, and shows a tendency to collect in masses, until in the perfect stoma very distinct chlorophyll bodies are present (Figs. X–XIV). The accessory cells grow in about the same ratio as the stoma, so that they bear nearly the same proportion to the completed stoma that they did to the stoma when they were first formed. The air-cavity beneath the stoma is small at first, extending only beneath the stoma proper (Figs. XVII and XVIII), but it increases, extending under the accessory cells, until finally it occupies nearly the whole space beneath them (Figs. XV, XVI). These cells, as well as the stoma proper, increase little in depth after they are first formed. Occasionally the accessory cells are more in number, five or six, but this is rare, and when it does happen, they are crowded so as to occupy little more space than the normal number.

The first thing that strikes one on examining the epidermis of Indian corn, is the peculiar form of the stomata. The guard-cells, apparently, instead of being crescent-shaped, are nearly triangular, and do not meet at the ends, as would be expected.

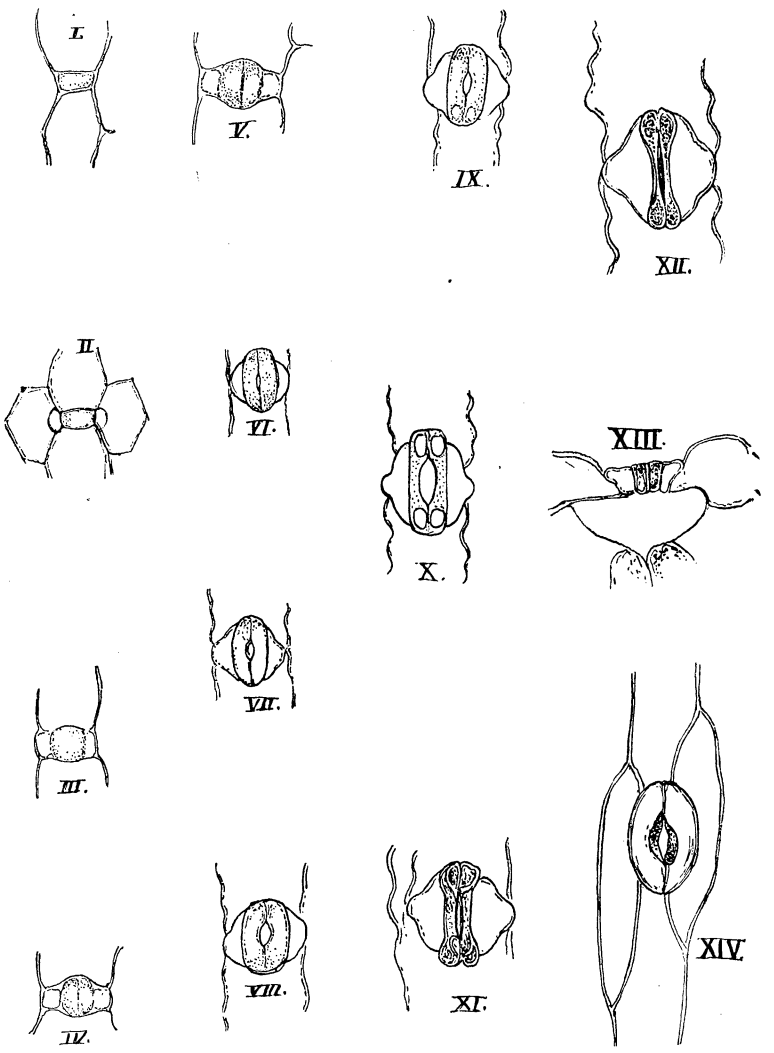
If, however, the younger forms of the stomata are examined, it is perceived at once, that what were taken as guard-cells are not really such, but are cells corresponding to the accessory cells described in Tradescantia. In the mature leaf the epidermal cells are long and narrow, and have a very marked sinuous outline; but in the young leaf they are proportionately much shorter, and have a nearly straight outline. The formation of a stoma is as follows:

A vertical septum is formed across the end of a cell, shutting off a cell, which is very short (Plate II, Fig. I). This cell, however, lengthens rapidly, and soon is nearly square in shape. The stomata are at first formed in rows, but when mature this regularity is not very obvious. Almost as soon as the mother-cell of the stoma is formed, two small cells, at the sides, are cut out from the adjoining epidermal cells, much as in Tradescantia (Fig. II). These at the outset scarcely keep pace with the development of the mother-cell; but finally grow much faster, and in the end so crowd it as to completely change its shape. The mother-cell rounds off and divides, developing for some time very much as any ordinary stoma (Figs. III–VIII); but when it is about half grown there is a marked change. The stoma gradually begins to lengthen (Fig. IX), and the accessory cells which have hitherto been small and unimportant, begin to grow more rapidly, beginning also to show their triangular form. The stoma becomes more and more elongated, and at this stage is nearly rectangular (X), and two or three times as long as broad. Distinct vacuoles are usually present and situated at the ends, but these soon disappear, and their position marks the place of greatest condensation. From this time, the accessory cells form the most conspicuous part of the stoma. They grow toward the center of the stoma, and in consequence the guard-cells become more and more contracted, until the stoma itself, instead of being oval, as it was when half grown, has become somewhat dumb-bell shaped, and to a casual observer, the accessory cells, which are no part of the stoma proper, might easily seem to be the guard-cells, while the real guard-cells are so altered that they look like mere thickenings around the pore.

The shape of the accessory cells varies somewhat, but is, in general, approximately triangular, or, rather, three-lobed; but sometimes the lobes are so indistinct, that the cells are nearly

semicircular, while at others the lobes are so strongly marked as to make the cell approach a trefoil. Occasionally, as in Trades-

PLATE II.



INDIAN CORN.

cantia, the ordinary number of these cells is increased, and an additional one is present; but this is apparently formed by the

division of one of the others. Occasionally stomata are also found on the underground stems for some distance below ground. In all such cases they are without the accessory cells, and the guard-cells are of the ordinary shape, and not compressed.

As far as I have been able to ascertain, the form of stomata found in Indian corn is general among the grasses, but usually the stoma proper is neither so narrow nor so much constricted; this is, however, not so in all cases.

In the examination of both these plants, it is necessary to examine the youngest attainable growth, as the stomata are fully formed very early. In Tradescantia, I took the bases of the youngest leaves that I could procure, those that scarcely showed at all without removing the outer leaves, and taking the youngest parts of this, placed it under the microscope without attempting to remove the epidermis. The leaf at this stage of its growth is so thin as to be almost transparent, and by careful focussing, I was able, with little difficulty, to get the youngest forms. In corn I made an oblique section of the stem quite low down, and taking out the bundle of young leaves from within the stem, treated them the same way as in Tradescantia. Only by doing this is it possible to get at the young forms, since any leaf which is firm enough to allow the epidermis to be removed, would show only forms complete, or nearly so.

In the Tradescantia the stomata are confined to the lower surface of the leaves, the upper surface being absolutely without them, while in Indian corn, although they are much more numerous on the lower than on the upper side, they are still found to some extent on the latter.

On first examining the younger forms of the Indian corn stomata, I thought that the accessory cells were formed from the mother-cell by internal division; but after having examined the formation of the accessory cells of Tradescantia, I was struck by the similarity of the two, and on reëxamination of the Indian corn, I was convinced that they were cut out of the adjoining epidermal cells, and were in all respects identical with those around the stomata of Tradescantia.